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Research Report

A Non-Destructive Radioanalytical Method for the Determination of Gallium in Substituted Yttrium Iron Garnets

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A Non-destructive Radioanalytical Method for the Determination of Gallium in Substituted Yttrium Iron Garnets

THE substitution of diamagnetic ions with a valence of three for iron in garnets modifies both the saturation magnetization and the magnetic anisotropy of these materials. So far, there has been no correlation between the extent of the changes in these parameters and the amount of substituted ion. For these reasons and because the amount of garnet material was extremely limited, usually of the order of micrograms, a rapid, non-destructive method for the determination of gallium in yttrium iron garnet was undertaken. The empirical formula of this substituted garnet is $(Fe_{5-x}Ga_x)Y_3O_{12}$, where x is typically in the range of 0·05–0·25.

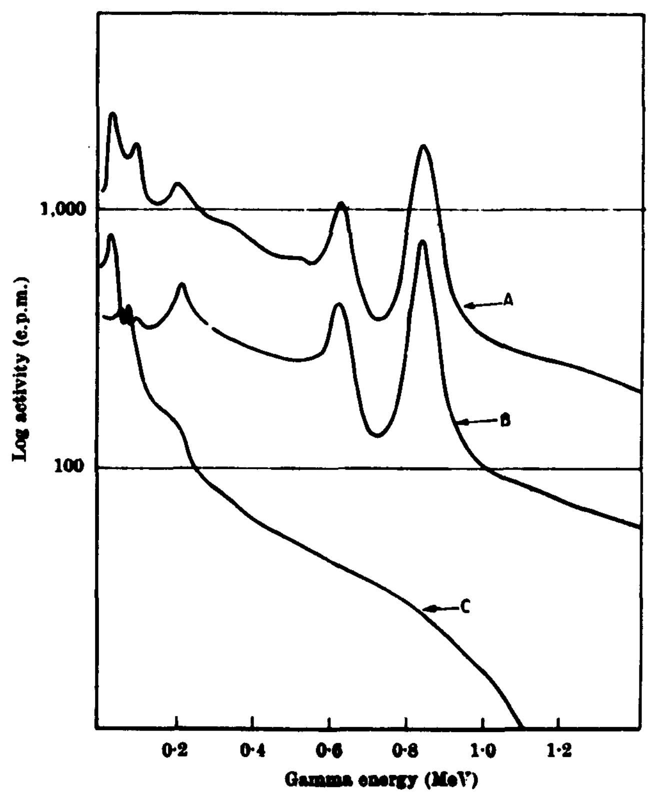

Fig. 1. Gamma spectra of three samples as indicated. Intensities are relative. Spectra taken 4 h after irradiation. *A*, Gallium yttrium iron garnet; *B*, gallium standard; *C*, yttrium iron garnet

Attempts to measure the gallium content by X-ray fluorescence methods failed because of the anomalous results obtained between single crystals and powders of the same composition. A non-destructive radioanalytical scheme based on neutron activation and γ-ray pulse-height analysis was developed in this laboratory.

Gallium exists as two stable isotopes, gallium-69 and gallium-71. Thermal neutron irradiation of the former produces the β-emitter (99+ per cent) gallium-70, but because γ-spectrometry was to be used for measurement of the induced activity, it was not of interest in this work. Under the same irradiation conditions, gallium-72 is also formed. Its principal γ-lines are found in good yield at 0·63 and 0·83 MeV; its half-life was found to be 14·2 h, in good agreement with reported values[1].

The spherically shaped, gallium-doped garnet samples weighing from 200 to 300 micrograms were placed in an irradiation container together with a suitable amount of pure gallium metal and a garnet (*YIG*) containing no gallium. Samples and standards were then irradiated in the pneumatic facility of the Massachusetts Institute of Technology Reactor for 1 min at a thermal flux of 8×10^{12} neutrons cm^{-2} sec^{-1}.

The induced γ-activity was analysed for both energy and decay characteristics using a 512-channel analyser coupled to a 2-in. well-type sodium iodide (Tl) crystal detector.

Fig. 1 shows some typical results. The upper curve, *A*, is the γ-spectrum of the gallium-doped garnet. The middle curve, *B*, is that due to the pure gallium metal, and the lowest curve, *C*, is that of the pure gallium-free yttrium iron garnet. The principal peaks in the two upper curves are found to be at 0·63 and 0·83 MeV in agreement with the literature[2] γ-energy values for gallium-72.

Quantitative results are obtained by measurement of the areas under the samples and standard 0·83-MeV peaks after applying the usual background, decay, aliquoting and geometry corrections. An unusual correction, possible because of the versatility of the equipment used herein, was the subtraction of the activity under the aforementioned peak due to the pure yttrium iron garnet. This correction ranged from 2 to 4 per cent. Some results obtained are shown in Table 1.

Table 1. TYPICAL RESULTS OF THE RADIOACTIVATION ANALYSIS OF GALLIUM-SUBSTITUTED YTTRIUM IRON GARNETS

	C.p.m./μg in the 0·83γ peak*	Per cent gallium by weight
Sample *A*	61·5	12·2 ± 0·6
Sample *B*	50·4	10·0 ± 0·5
Sample *C*	47·9	9·5 ± 0·5
Standard	506	

* All corrections applied; time of determination was 4 h after irradiation.

Statistical, weighing, and other known errors amounted individually to less than 1 per cent, and the standard error of the method, given as the standard deviation, is calculated to be not more than 5 per cent.

A search of the literature[3] indicates that no single interfering element or combination of elements could give a spectrogram with γ-energies and decay characteristics similar to that found.

Finally, it should be pointed out that because of the short irradiation time, residual activity, after a few days decay, is minimal and the garnets may be recovered for additional investigations.

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[3] Strominger, D., Hollander, J. M., and Seaborg, G. T., *Revs. Modern Phys.*, **30**, 585 (1958).

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